

## SOME HINTS AND INSTRUCTIONS TO LAB 5

### Part A

#### **DEMO (Flat fading and frequency-selective fading)**

The LO signal to PROPSIM must be 500 MHz higher than the input signal when  $f_c = 400$  MHz, that is  $f_{lo} = 900$  MHz. The LO signal level should be 10 dBm.

#### **L1 (2-tone measurement of spaced-time spaced-frequency correlation)**

*Measurement instructions:* The spectrum analyzer GPIB address should be 20. You can check it from Configuration/Setup. The GPIB address is required by the LABVIEW program.

Make sure that the center frequency of the PROPSIM is 400 MHz and input signal level is set correctly to the simulator parameters.

Resolution bandwidth can be changed from the Coupling menu of the spectrum analyzer. Use automatic video bandwidth selection. The sweep time of the spectrum analyzer should be less than 10 ms. Otherwise the measurement is too slow compared to channel change.

Important: Make sure that averaging is off from the Trace menu of the spectrum analyzer. Otherwise you will get useless measurement results, since deep fades will be averaged away.

You have to position a marker on top of each frequency peak before running the program. The *read\_markers.vi* program reads 4-5 marker values per second per marker. Reading a total of 1000 marker values (500 each) takes about two minutes. In the output file the marker values are interleaved: {m1, m2, m1, ...} .

You have to reposition the markers on top of the frequency peaks after you change the sine wave frequency of the AWG. To do this you have to push the Status/Local button of the spectrum analyzer and then use the marker functions again.

*Measurement postprocessing:* Do not forget to delog the measurement results before computing correlation. To compute correlation you may employ MATLAB functions `corrcoef`, `xcov` or `xcorr`. Note that `xcorr` does not automatically remove mean from the signal like `xcov` does. Here is the familiar formula for computing covariance<sup>1</sup> coefficient between two random variables  $\bar{X}$  and  $\bar{Y}$ :

$$c_{xy} = \frac{E[(\bar{X} - m_x)(\bar{Y} - m_y)]}{\sigma_x \sigma_y}.$$

$m_x$  and  $m_y$  are the mean values of  $\bar{X}$  and  $\bar{Y}$ , and  $\sigma_x$  and  $\sigma_y$  the respective standard deviations.

**Decibels:** Amazingly many Master of Science wannabes have forgotten about decibels. Remember that when you want to express an amplitude quantity (such as an rms value) in decibels, use  $20 \lg(\cdot)$ .  $10 \lg(\cdot)$  is used for power quantities (such as rms squared, or mean square value). The measurement results in experiments L1 and L2 are in dBm.

## L2 (Measurement of LCR and AFD)

*Measurement instructions:* You can use the same measurement setup as in L1, but to generate the 1-tone signal turn vector modulation off from the vector signal generator and use the signal generator to feed a pure carrier signal to the channel simulator.

*Measurement postprocessing:* You have to somehow find a way to compute how many times a signal crosses a certain level  $R$ . An example of how to do this is shown below. You may figure out a more clever and compact way of doing this.

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<sup>1</sup> Recall that difference between covariance and correlation is that in covariance mean of the random variables is removed. If both RVs are zero-mean, covariance and correlation are identical operations, as are the `xcorr` and `xcov` functions.

```
function l=lcr(s,R);  
  
% Find the number of positive-going  
% level crossings in a signal.  
%  
% l=lcr(s,R). s is the signal vector,  
% R is the level threshold. l is the number  
% of times the signal crosses level R  
% in the positive-going direction.  
  
s=s-R;           % Normalize level R to zero  
  
% Some preprocessing...  
s=sign(s);  
g=buffer(s,2,1,'nodelay');  
gg=sum(g);  
  
I=find(gg==0);           % Indices of negative and positive zero-crossings  
l=length(find(g(1,I)==-1));
```

Do not forget to delog measured signal when you plot the histogram. It would be useful to plot the theoretical Rayleigh pdf with the same variance as the measured signal to the histogram for comparison. Histogram can be plotted with the MATLAB function `hist`; use a “reasonable” amount of bins in the histogram. Rayleigh pdf can be most easily plotted by using the function `raylpdf` from the statistics toolbox. The maximum-likelihood estimate of the parameter  $B$  of the Rayleigh distribution is

$$\hat{B}_{ML} = \frac{1}{2N} \sum_{i=1}^N x_i^2,$$

where  $N$  is the number of samples.

### L3 (Measurement and analysis of LTV system functions)

#### Directly measured LTV system functions

*Measurement postprocessing:* The first problem here is to dig up the time-variant impulse response by matched filtering or correlation. You may try functions `xcorr`, `conv`, or `filter`. The end result will be the same if you use them correctly. Using a fast computer with lots of memory is recommended. What “fast” means depends on how patient you are. Example: 500 MHz Pentium III with 256 Mb RAM produces a 1024x512 IR matrix in about 3 minutes (time may vary according to implementation).

Since three bursts of the 127-chip pn code were sent for each snapshot, you will see more than five channel taps at the correlator output. The first tap is the one with

constant amplitude, and we know that there were five taps in the channel model. The channel taps with a visible noise floor ("grass") are duplicates. Simply choose the "correct five" (see Figure 1) and discard the rest. You should make the length of the signal in delay domain a power-of-two for efficient FFT. In time domain the length should be 1024 samples as instructed. Figure 1 portrays an example of time-variant IR with 32 IR snapshots plotted. In delay domain the length is 512 samples.

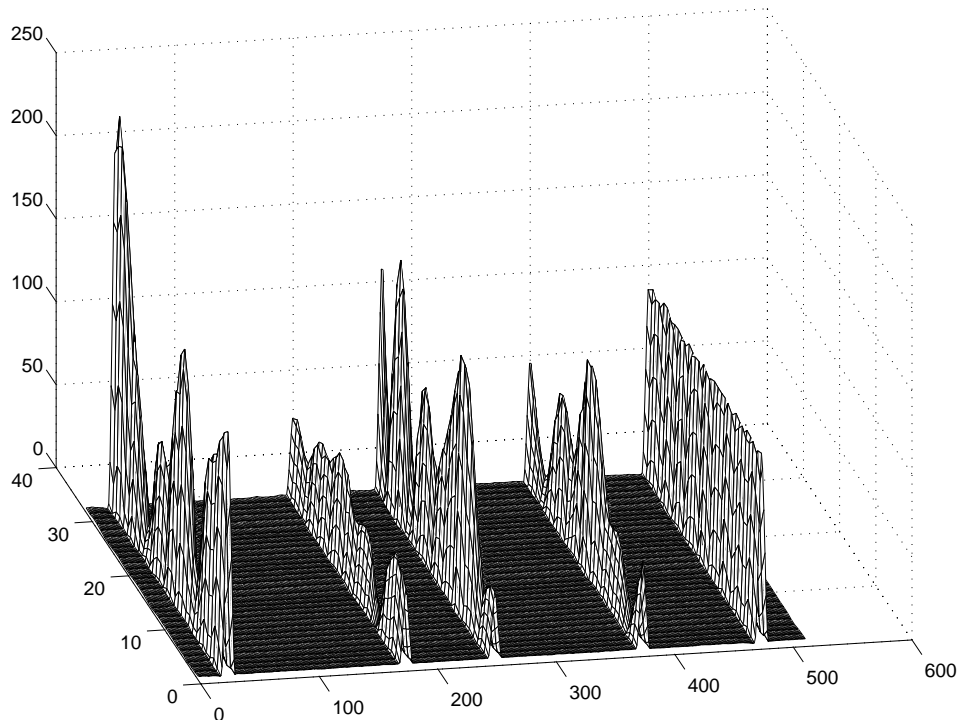


Figure 1. An example of time-variant IR (absolute value). This is what you should obtain.

You can make a script that processes the whole measurement result, or cleverly use command line. Document your actions to the report. If the script is long, you may put it to an appendix.

Once you have constructed the time-variant IR you can find the other three LTV system functions by using `fft`.

### Statistical LTV system functions (estimated)

- c) Frequency correlation function:  $\phi_H(\Delta f, 0) = E[H(f, t)H^*(f + \Delta f, t)]$ . How to estimate this? Answer: Take autocovariance<sup>2</sup> with `xcov` along the  $f$  axis of each

<sup>2</sup> Once again, if the signal is zero-mean, this will produce the same result as `xcorr`.

frequency response snapshot, and average all autocorrelations. Since  $\Delta t = 0$ ,  $\phi_H(\Delta f, 0)$  is only a one variable function.

- d) The other statistical LTV functions follow similarly, see page 766 of [Pro95] for an illustration of the subject.

## **Part B**

*Measurement set-up for L4-L6:* The LO signal frequency to PROPSIM must be 500 MHz lower than the carrier frequency. The LO signal power level should be 10 dBm. Be sure to set the center frequencies correctly in the PROPSIM parameter set-up. The channel models have been configured so that the downlink signal should go through channel #1 (CH1 IN/OUT), and the uplink signal through channel #2 (CH2 IN/OUT).

*Table 1. Settings of the PROPSIM parameters for BER measurement set-up.*

<b>Parameter</b>	<b>Channel #1 (DL)</b>	<b>Channel #2 (UL)</b>
Center frequency	1806 MHz	1711 MHz
Input level	-15 dBm	6 dBm
Output level	-20 dBm	-10 dBm

CTS-55 settings<sup>3</sup>: A default configuration having the correct attenuation settings has been made under the name *HefaultMobile*. If that doesn't work you have to do the following adjustments.

MS transmit power must be set to about 10 dBm; this can be done in the Config menu of the MS test/Wait sync screen. The input attenuation must be set to 20 dB, output attenuation 0 dB; these must be set from the master configuration from the main menu of CTS-55.

<sup>3</sup> All these settings apply only when the measurement set-up identical to the one shown in the figure of the main document is used.

During error measurements do not trust the received power level (RXLEV); this is measured by the MS and it is not a reliable result. Instead use the attenuators to control the power that the MS receives. You can do this because the attenuation of the cables and attenuators is known very accurately, and the PROPSIM output level (-20 dBm, see Table 1) is also known.

Table 2. Measured attenuations for the measurement cables in the student lab.

Cable type	Attenuation@1800 MHz (dB/100m)	Notes
RG214	34 dB	
Nikkai 3D-2W (RG58)	70 dB	Grey flexicable
RG213	34 dB	
Power splitter ZAPD-21	3.4 dB	The same loss for combining direction.

## L4 - L6

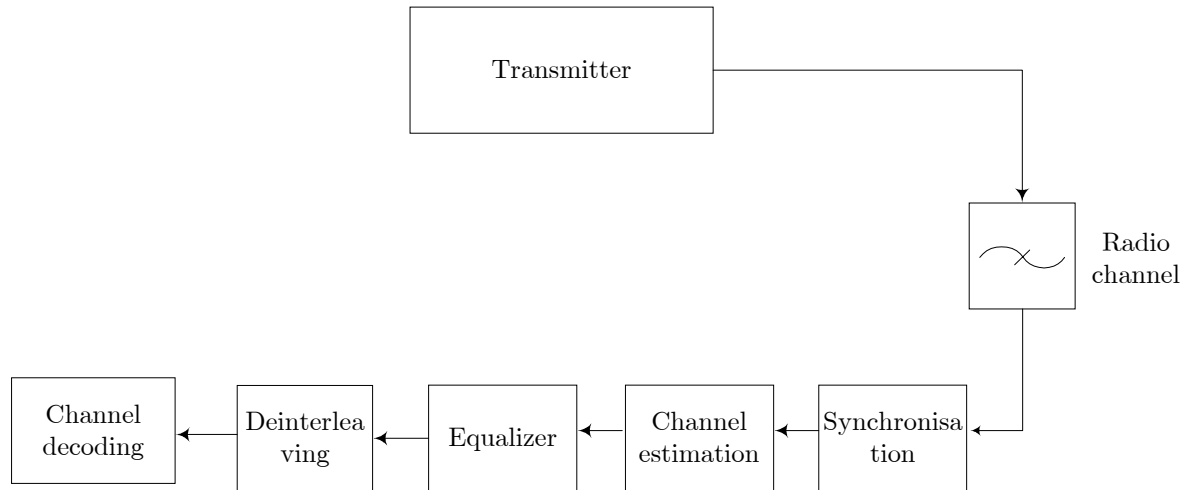
*Measurement instructions:* You can read all xER<sup>4</sup> values from the screen of the GSM tester if the measured FER is stable. When the FER value “jumps around” you can measure it several times ( $\geq 5$ ) using the `cts_ber2.exe` program. The program writes the measurement results to a file. You can average the results during postprocessing.

*Measurement postprocessing:* It is perhaps most illustrative to plot one error measure for all propagation conditions in the same plot. For example, you may plot RBERIb for 1-tap static and 1-tap Rayleigh in the same plot.

When pondering about reasons for the xER behavior you should think about the block diagram of a digital communications receiver for fading channels. Components of the receiver include synchronization, channel estimation, equalizer, deinterleaving, and channel decoding units.

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<sup>4</sup> xER denotes RBERI, RBERIb, and FER.



*Figure 2. Blocks of a typical radio receiver for frequency-selective fading channels.*